Dynamics and Structure of Baroclinic Tides in Mamala Bay, Oahu, Hawaii

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LONG-TERM GOALS

To understand the dynamics, scales and significance of large (100-m) internal vertical motions at the semidiurnal (M2) frequency, previously observed in Mamala Bay, Oahu, Hawaii

OBJECTIVES

This project aims to map the structure and understand the dynamics and significance of these motions. They were first seen in moored temperature and velocity records spanning Mamala Bay. Strong (> 1 knot) currents at the headlands at Barbers Point and Diamond Head merge into large (> 100 m) displacements at the bay center.

These motions and similar ones at other embayments have the potential to impact:

- internal-wave and mixing processes at the Hawaiian Ridge and other regions of strong topography
- spread of pollutants in this and other bays
- modulation of the acoustic environment outside Pearl Harbor

APPROACH

This year has focussed on analysis of new observations (4-day shipboard survey plus 2-month moored-profiler deployment) in an attempt to synthesize spatial and temporal evolution of an energetic internal tide.

New Observations

A McLane moored profiler (Figure 1) from the WHOI moored equipment pool collected hourly samples from 8/11/02-10/01/02 of full-water-column temperature, salinity and velocity at a site in 400-m water depth (Figure 2). Basic moored observations are

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summarized in Figure 3. I have been so pleased with these data that I have since purchased three moored profilers on a DURIP.

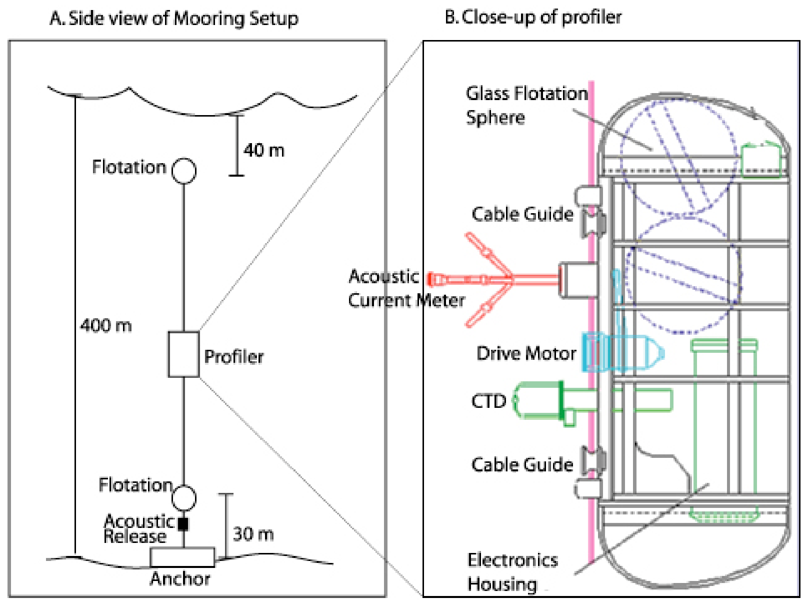


Figure 1: (Left) Simplified schematic of the Mamala Bay mooring design. (Right) Close-up of the McLane Moored Profiler.

Intensive surveys from R/V *Revelle* (Figure 2) were conducted from 9/22/02-9/27/02 with the Pinkel Hydrographic Sonar and a towed instrument containing CTD's and up- and down-looking ADCP's (SWIMS2), following Mike Gregg's NSF-funded HOME nearfield leg.

To resolve the spatial structure of the oscillation from surveys without sacrificing synopticity, I designed a sampling pattern consisting of four legs (Figure 2), each of which could be completed in 1.5 hour, providing a complete occupation every three hours (4 points per M_2 tidal cycle). Each was repeatedly occupied for 24 hours (nearly 2 M_2 tidal cycles). The mooring (black dot) "anchored" these spatial surveys within the context of a much longer (2 months) time series. The combined spatial/temporal information from the mooring and the survey provided a rich view of the structure and evolution of the oscillation.

WORK COMPLETED

- Execution of 4-day intensive survey using SWIMS and the R/V Revelle sonar
- Deployment and recovery of the McLane Moored Profiler
- Post-cruise calibrations of all instruments
- Analysis of data
- Presentation of results at HOME workshop in Timberline, OR (8/03)

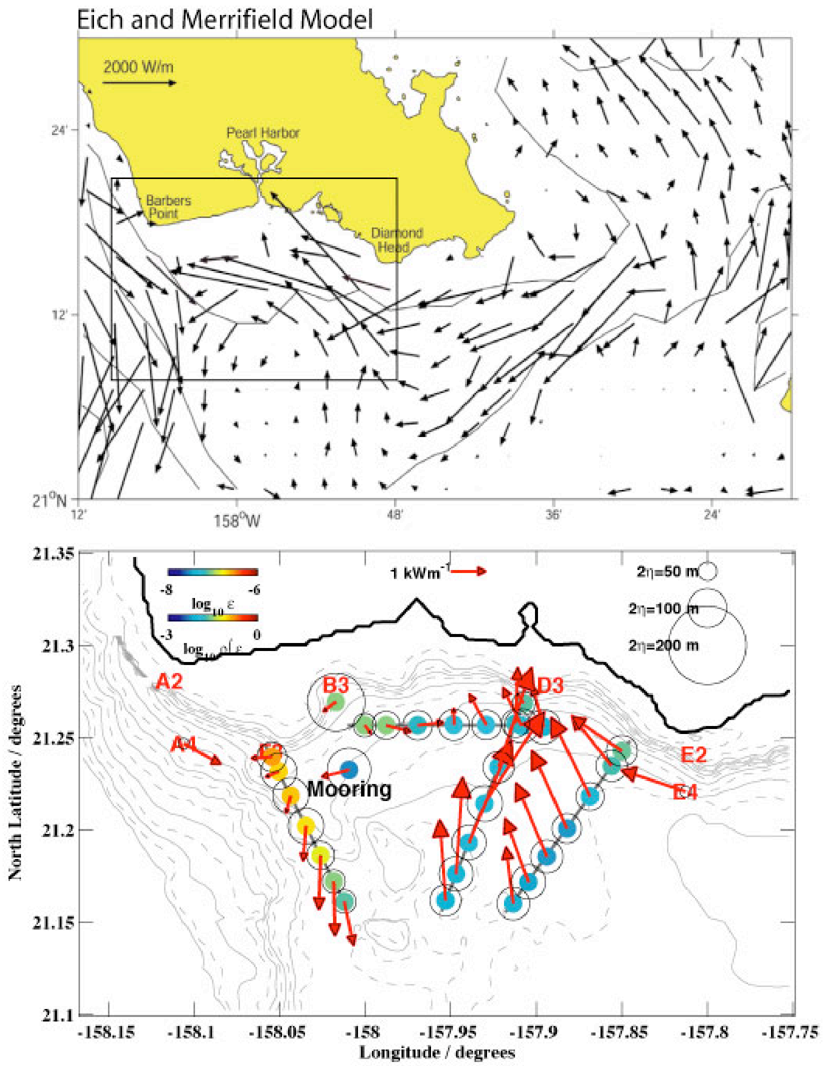


Figure 2: SWIMS energy flux and dissipation survey. (Top) Model energy flux from Eich and Merrifield (2003). The region in the lower panel is indicated. (b) Observations of energy-flux (arrows) and depth-integrated dissipation rate inferred from overturning scales (colors).

RESULTS

Significant findings are:

• The strongest displacement signals occur in the western portion of the bay and decay offshore with a scale of about 6 km.

• The energy flux mapped using all the SWIMS legs and overplotting the new and historical moorings produces a complex but coherent picture that is consistent with Eich and Merrifield's model results (Figure 2). There appears to be a strong flux convergence east of B3, potentially implying large dissipation rates there. However, the maximum observed mixing rates (from overturning or Thorpe scales) are further west. This spatial offset is puzzling and warrants further analysis.

• Two-month depth-time series of displacement, energy flux and dissipation rate all peak 2-3 days after the spring tide (Figure 4), implying propagation from a remote site. Dissipation rate (inferred from Thorpe scales) modulates by a factor of 50 with the spring-neap cycle (bottom panel).
• Temporal variability. Figure 4 shows lulls in energy flux and changes in the relationship

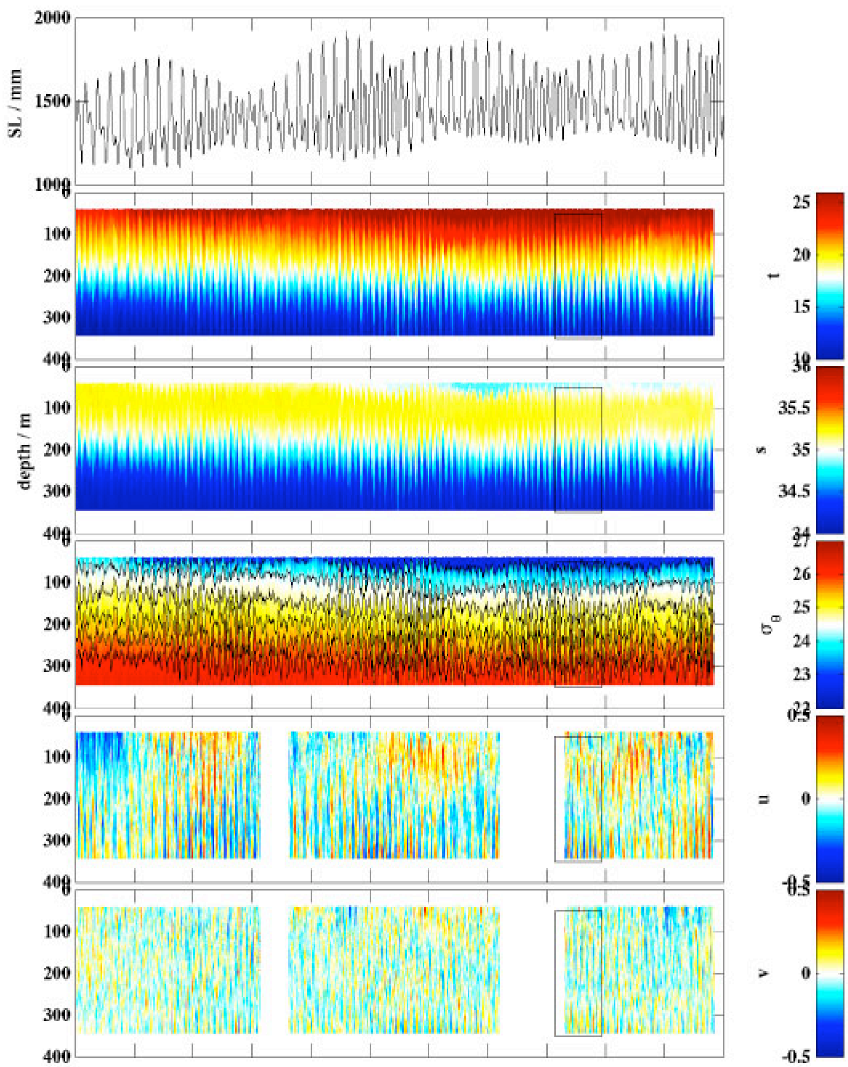
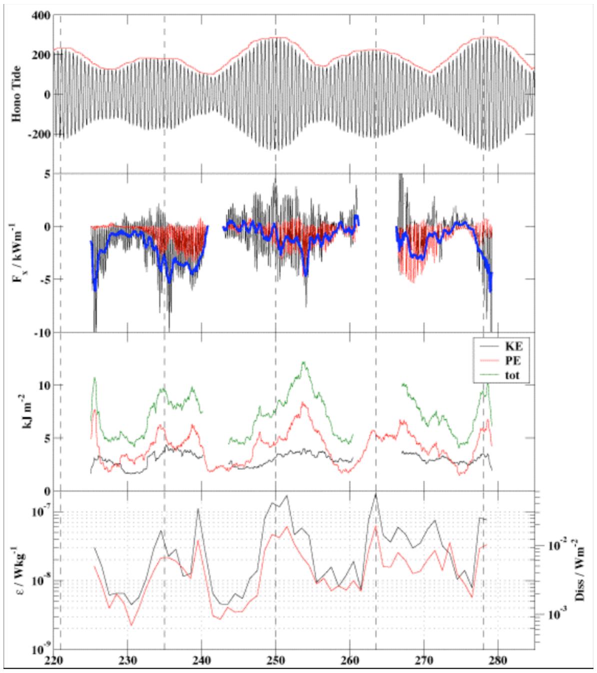


Figure 3: Moored observations. From top: Honolulu sealevel, moored temperature, salinity and potential density, and zonal and meridional velocity. Selected isopycnal depths are plotted in (d).

between energy and energy flux. In addition, the vertical structures change in time (Figure 2).
• With the simultaneous space-time surveys, westward phase propagation can be directly observed (Figure 5), confirming the westward u'p' flux estimates (Figures 2, 4). The phase speed is about 0.5 m/s, consistent with a mode-1 Kelvin wave.



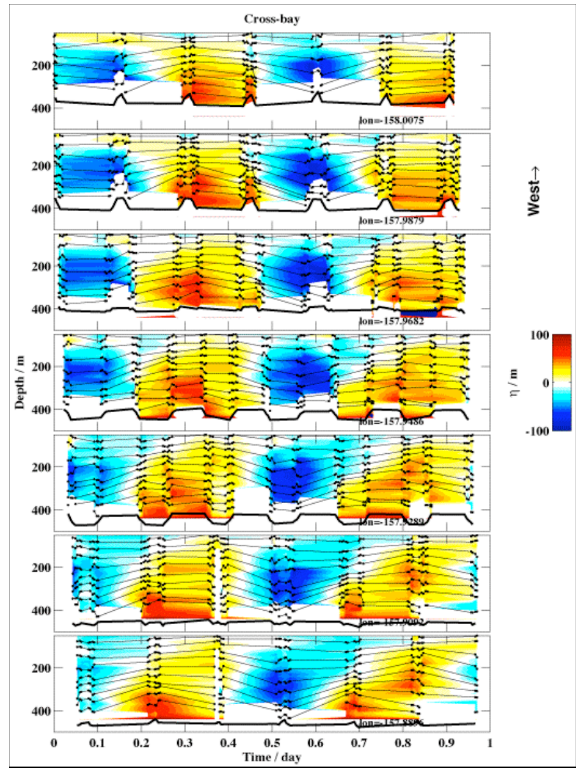


Figure 4 (above left): Time series of depth-average moored quantities. From top: M2 sealevel at Honolulu, eastward energy flux (blue), energy, and dissipation rate from overturns (black). Spring tides are indicated with vertical dotted lines.

Figure 5 (above right): Isopycnal displacement (colors) and depth (black lines) from a sample survey leg. Each panel is a time series at a specific longitude, increasing eastward toward the bottom of the figure. Observation locations are shown with dots.

IMPACT/APPLICATIONS

The magnitude, structure and phasing of this oscillation impact other internal-wave processes at the Hawaiian ridge. I expect the results to be relevant both to the HOME goals of determining the role of topographic mixing in the ocean, and to the general problem of forced responses in embayments. In addition, the surface signature of the oscillation modulates Honolulu tide guage records, which Colosi and Munk (manuscript submitted) have shown may be indicators of climate change.

TRANSITIONS

We are developing the combined moored/survey approach in other projects. The skills and techniques being learned in this project are aiding our general goal of moving toward

3D-plus-time oceanography. In a proposed continued analysis effort, Ms. Kim Martini will perform comparisons with the Merrifield model as part of her thesis.

RELATED PROJECTS

The energy-flux techniques I have been using and developing tie in strongly to my Young Invetigator project, "Global Mapping of near-inertial and tidal energy fluxes."

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